Integrating Geospatial Operations into Next Generation Design Processes

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Summary: The demand for 3D design processes, accelerated production schedules, and increased collaboration across operations places continued pressure on geospatial operations to adapt their processes in support of these increasingly demanding design and production environments. Given the comprehensive nature of modern geospatial data, the concept of Digital Twins has rapidly emerged as a potential solution. In this paper we take a pragmatic look at the realities of Digital Twin production and submit the argument that under dynamic conditions, the concept of a Digital Twin as a "single" source of truth is not viable. As a solution, the TopoShare®/TopoDOT® process is introduced to efficiently execute an "on-demand" production process responding to requests for individual models, analyses, and other forms of Digital Twins where and when they are needed. Highlights of the TopoShare®/TopoDOT® process include positioning geospatial operations in control of the Digital Twin production resulting in a quality-controlled process executed at the lowest possible cost.

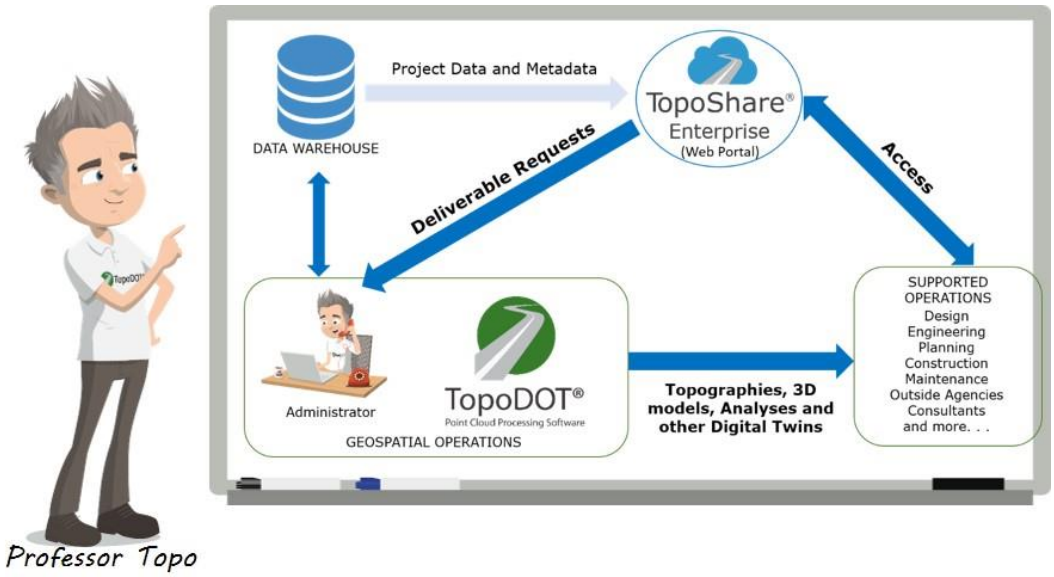


Figure 1: The TopoShare Process

1. The Challenge Imposed by Next Generation Design Processes on Geospatial Operations

Transportation corridor, civil infrastructure, and other AEC applications increasingly require design processes to be executed within the context of a full 3D CAD environment. This migration to 3D is strongly correlated with demands for increasingly sophisticated 3D virtual representations of real-world models produced by geospatial operations. In today's vernacular, such representations are commonly referred to as Digital Twins. Per the *Digital Twin Consortium (www.digitaltwonconsortium.org)*;

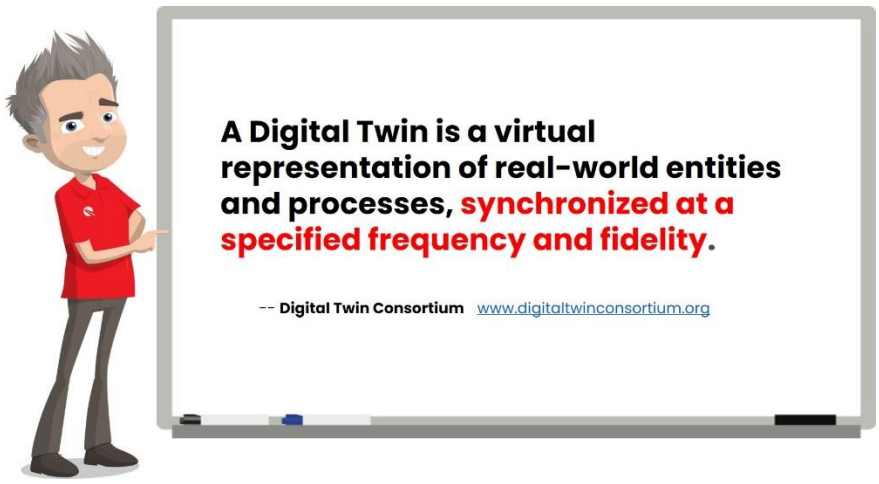


Figure 2: Digital Twin Definition

Geospatial operations have long been supporting design processes with virtual representations of real-world geospatial entities, so essentially Digital Twins are nothing new. The primary challenge to any geospatial operation is achieving synchronization of in frequency and fidelity as accelerating schedules implicitly necessitate increased frequency of Digital Twin updates. Furthermore, Digital Twin fidelity requirements meeting the unique and changing project objectives across the spectrum of supported operations vary dramatically. The resulting aggregation of requirements from different operations is never clearly defined. Thus, in order for a single Digital Twin to meet the broadest range of applications, the requirements naturally tend toward the highest and consequently most expensive level of fidelity. The result is that geospatial operations are typically confronted with requirements of Digital Twin frequency and fidelity that place unrealistic demands on manpower, budget and schedule.

2. Optimizing the Digital Twin Production Process

2.1. The Digital Twin Challenge

The aforementioned challenges facing geospatial operations stem primarily from a misconceived notion of a single Digital Twin serving as a single source of "truth" to be referenced across operations. This implicitly requires a top-down approach to defining Digital Twin requirements broad enough to serve a myriad of potential project objectives. Consequently, a geospatial operation is tasked with anticipating the needs of numerous supported operations in order to define the form, fidelity, and frequency of a single Digital Twin that might serve at least a majority of the project objectives. This top-down approach to Digital Twin production places geospatial operations in a largely untenable situation.

The Digital Twin concept as applied to civil infrastructure applications reinforces this contention. A quick review of case studies and general discussions of Digital Twin technology generally reveals a wide range of inconsistency in the form, fidelity, and frequency of models employed in various applications.

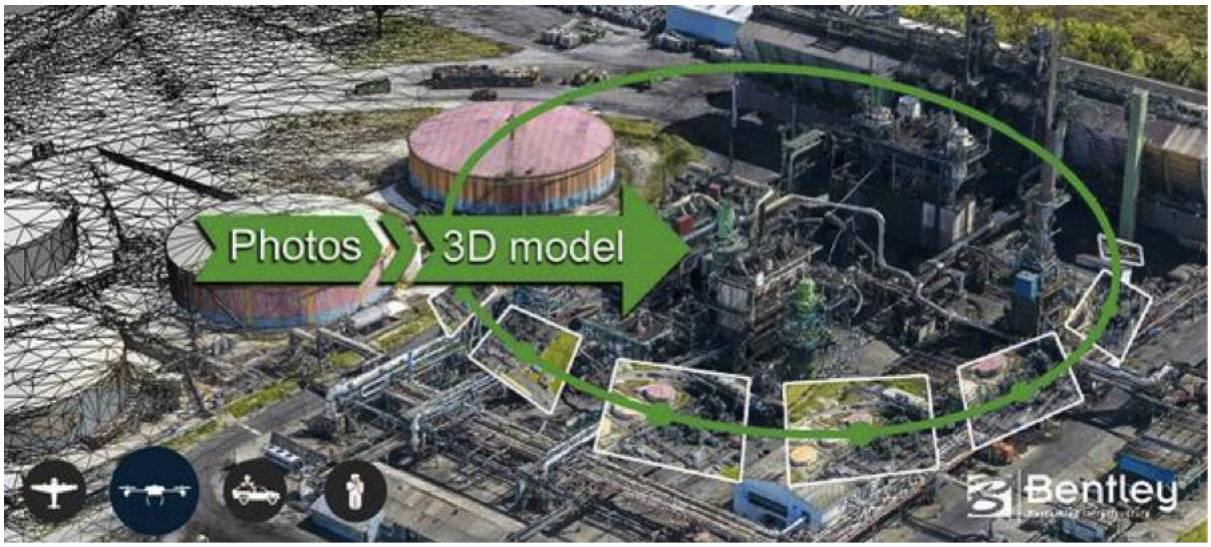
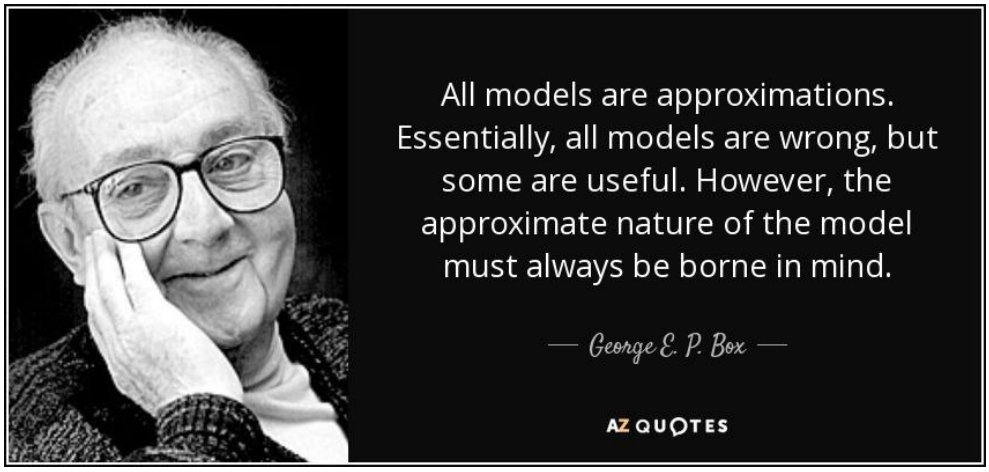


Figure 3: Wide area mesh form of Digital Twin is generally limited to planning and conceptual design applications

For example, the wide area topographic mesh employed is commonly referred to as a Digital Twin. Such models are relatively popular given their automated production and low cost. However, while useful as a reference in planning and conceptual design applications, such models typically lack the precision and accuracy to support most design, engineering, and construction applications. Moreover, lacking any lineage to certified survey control reference coordinates, precision and accuracy cannot be reliably verified and documented. This

deficiency largely precludes their support of many design, engineering, and construction processes. Therefore, alternative forms of Digital Twins must be produced to satisfy the requirements of these operations. This begs the question, is not the obvious need for multiple Digital Twin models in direct conflict with the concept of the Digital Twin as the single source of truth? This statement seems self-evident!

2.2 Rethinking the Digital Twin



In the words of the British statistician, George E. P. Box, "*All models are wrong, but some are useful".* In practice, truly matching a geospatial model to the real world is fundamentally impossible, thus this statement holds true. And if all models are wrong, does it make sense to devote significant time, resources, and manpower to the development of a single Digital Twin to serve as a source of truth? What model could possibly meet the multitude of potential and widely varying specifications corresponding to the requirements of numerous operational applications? However, if some models are useful, would it not be a superior strategy to develop a unique Digital Twins with each designed to be useful in meeting the respective objectives of individual applications as encountered across all operations?

Embracing such a strategy essentially suggests a Digital Twin *On-Demand* production process! Envision collaboration between geospatial operations and supported design processes such that requirements for specific models, topographies, analyses, simulations, and other forms of Digital Twins are communicated directly to geospatial operations where and when they are needed! Geospatial operations could then quickly respond by assessing these immediate needs and producing a Digital Twin optimized in fidelity and price to meet specific application objectives.

3. On-Demand Digital Twin Production

Implementation of an On-demand Digital Twin production process as described above necessitates a deeper integration between geospatial operations and supported design processes than is typically the case. To achieve this level of integration, the TopoShare® product family has been designed. The TopoShare® process greatly enhances communication and collaboration across operations with respect to Digital Twin production.

3.1 The TopoShare® Solution

TopoShare® has essentially evolved out of the data management tool suite developed within the TopoDOT® Digital Twin production process. TopoDOT® has long provided a comprehensive tool suite for the organization and management of point cloud project data in support of feature extraction operations. These very successful and proven tools have been available to the TopoDOT® community for well over a decade. More recently their performance has been further enhanced and expanded into the TopoShare® product family. The TopoShare® family basically consists of the TopoShare® Administrator package, TopoShare® Basic, and TopoShare® Enterprise.

3.1.1 Implementing the TopoShare® Process

There are three fundamental steps in implementing the TopoShare® process. The first step is to organize your project data within the TopoDOT® desktop environment. TopoDOT® features highly automated and well-documented workflows for organizing all data, metadata, and supporting documents associated with each project acquisition into a directory structure optimized for storage and data transfer. TopoShare® is then configured to utilize your own Amazon S3 or Azure storage account; simply plug in your API key and TopoShare® will take care of configuring your Project Data Warehouse. Activating TopoShare® Enterprise permits the creation of a URL tagged to access projects within the users private Project Data Warehouse. Each URL is directed to the TopoShare® Enterprise web-page which presents the visitor with a catalogue of all projects associated with the URL. Interaction with the project data is executed as the TopoShare® Enterprise web-page seamlessly fetches the specified data from the Project Data Warehouse into the visitor's browser environment. Note that the visitor never has direct access to the Project Data Warehouse itself.

3.1.1.1 Building Your Data Warehouse—TopoShare® Administrator

The TopoShare® Administrator program is available for download by every TopoDOT® user at no cost. Project data and meta data files organized within TopoDOT® can conveniently be selected and copied into the TopoShare® Administrator. One click uploads all project data to your private Amazon S3 or Azure account while maintaining the organized structure and automatically establishing links to each data component within the project. This organized collection of projects is referred to as the Project Data Warehouse.

Figure 4: The Project Data Warehouse

A critical feature of Project Data Warehouse organization is that the provenance of all data is maintained by organizing all project files into a directory for storage and into its individual bin within the warehouse. Such organization is critically important *if the geospatial operations is to assure a quality driven process and accept responsibility for each Digital Twin delivered!*

Those within geospatial operations having administration privileges may then assign access rights to any member of the worldwide TopoDOT® community to any project or group of projects within the Project Data Warehouse. Note that only those with administrative privileges may upload data to the Project Data Warehouse. Those granted access by the geospatial administrator may only download data into their TopoDOT® application (or as a file to their local drive). Thus, the Project Data Warehouse serves as a common source of data across geospatial operations.

3.1.1.2 Data Warehouse Access within the TopoDOT® Community—TopoShare® Basic

TopoShare® Basic is resident within the TopoDOT® application. It essentially serves as a portal providing the user access to those projects within the Project Data Warehouse to which the user has received access permission from the geospatial project administrator. A geographical GUI makes locating and downloading project data, metadata, and even associated Digital Twins fast and easy.

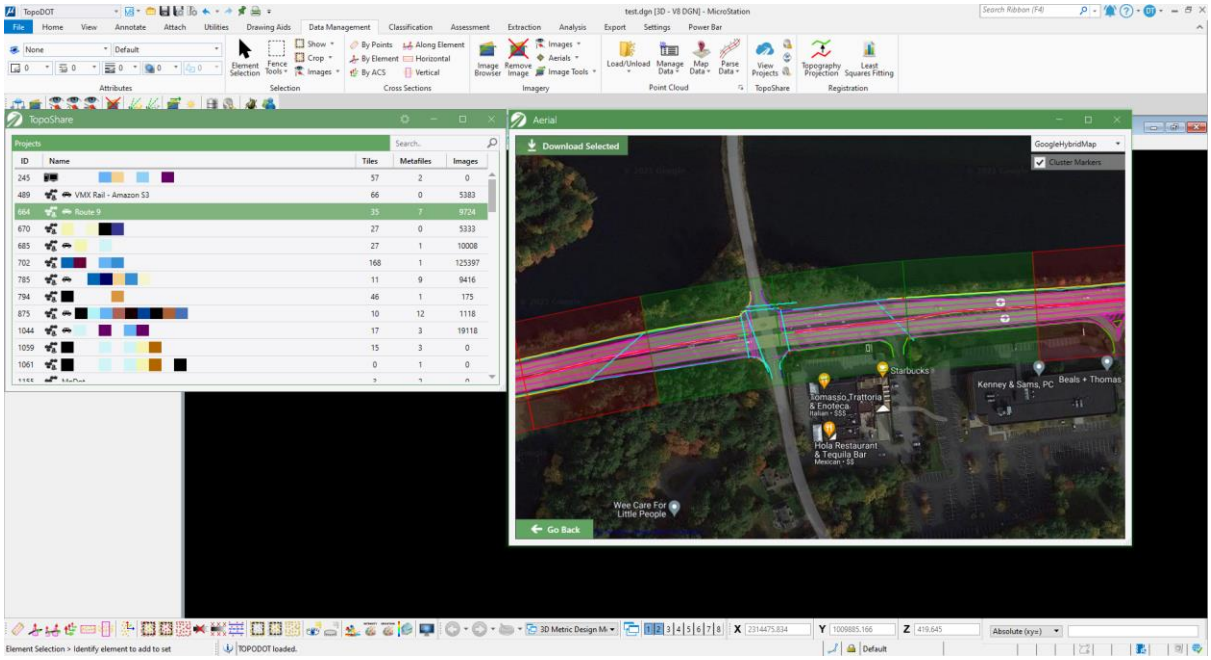


Figure 5: TopoShare Basic Access to Data Warehouse from within TopDOT

The geospatial project administrator exercises complete control over access to the Project Data Warehouse. User credentials and access permission to a specific project or group of projects will be assigned by the geospatial project administrator. TopoShare® Basic is the ideal solution for an administrator efficiently sharing data with technician teams employing TopoDOT® to produce Digital Twins and other products. Note also that data files can be transferred as files to the respective desktop of any technician. Thus, Digital Twin production is not exclusively confined to the TopoDOT® platform.

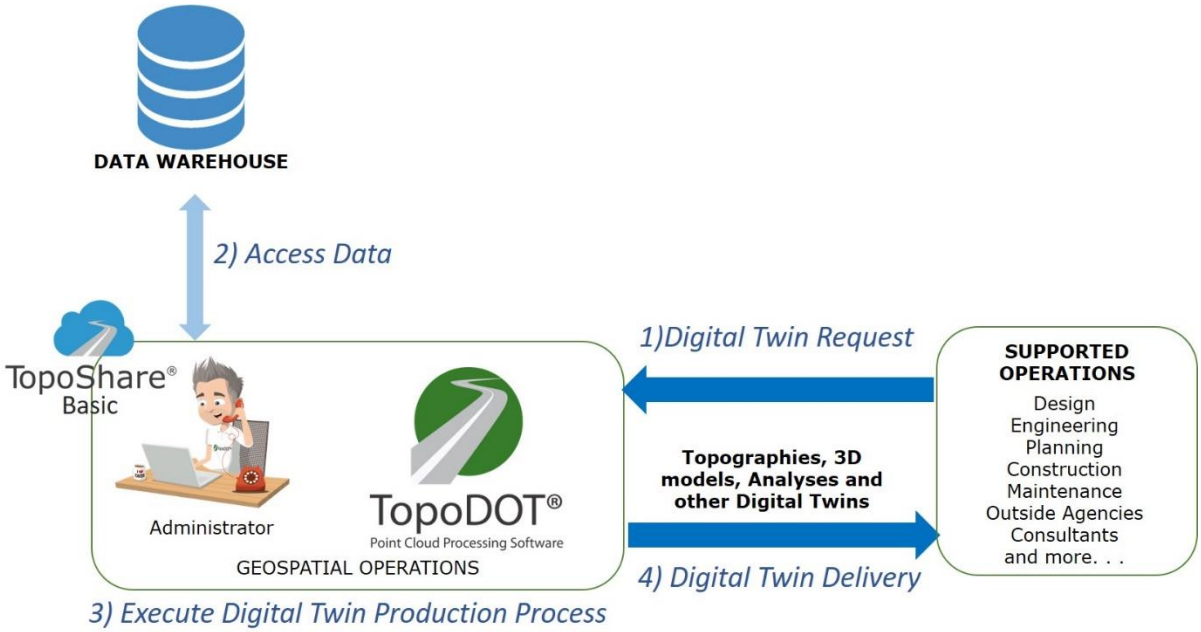


Figure 6: Use TopoShare® Basic to select appropriate project data to feed the Digital Twin production process

This process is extremely effective for managing and sharing data across geospatial operations. In fact, the TopoShare® Basic portal has been employed for many years within the highly successful TopoDOT® user community. As a standard TopoDOT® feature, there is no additional cost for the TopoShare® Administrator nor the TopoShare® Basic portal. Since the Project Data Warehouse is created in the user's private account and all operations for TopoShare are exclusively file-based, the only costs to the user are direct Amazon S3 or Azure storage and data transfer costs of a few pennies per gigabyte. Up to this point, the TopoShare® process adds no additional cost for management of an unlimited number of projects.

If there is one shortcoming to the TopoShare® Basic process, it is that the communication, collaboration, and productivity it enhances are confined primarily within the immediate TopoDOT® user community associated with the project. Thus the intrinsic value of this comprehensive geospatial data is rarely exploited beyond the initial Digital Twin delivery. In this process scenario, the Project Data Warehouse is essentially a treasure of potential value on an isolated island largely unexploited by planning, design, engineering, construction, maintenance, and other operations.

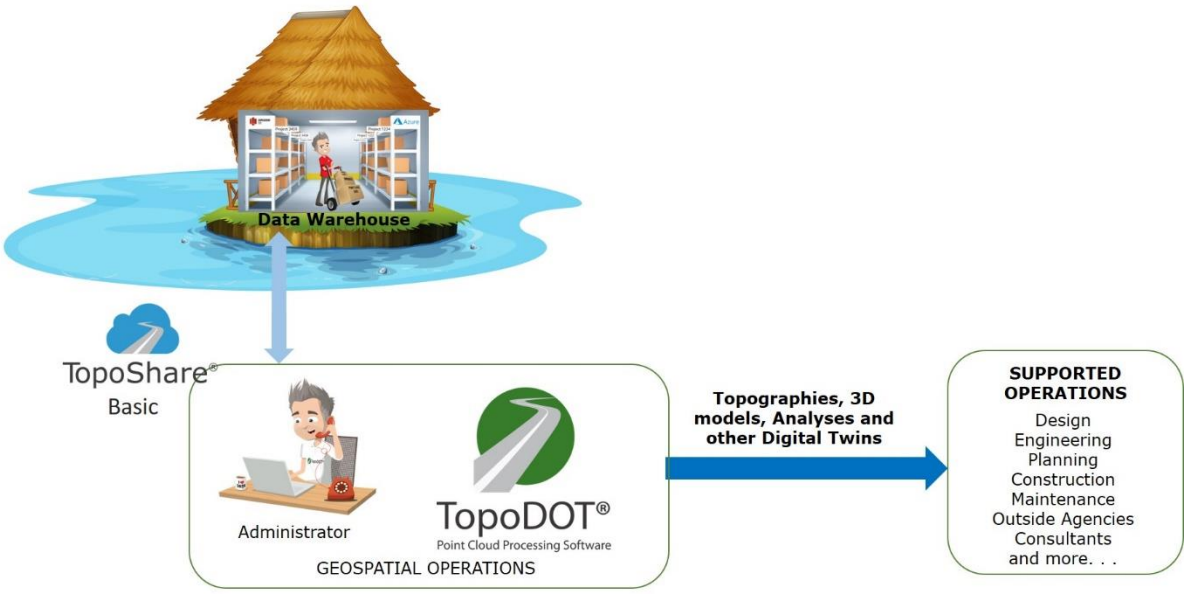


Figure 7: Without Operations access to the Data Warehouse the full value of this data is rarely exploited

3.1.1.3 Expanding Data Warehouse Access Across Operations—TopoShare® Enterprise

TopoShare® Enterprise is designed to offer unlimited access to the geospatial Data Warehouse beyond the TopoDOT® user community. TopoShare® Enterprise is essentially a web-page that will provide unlimited access to individual geospatial projects or groups of projects located within a geospatial administrator's respective Project Data Warehouse. The geospatial administrator need only select individual or group of projects from his catalogue list provided in the TopoShare® Administrator. A single click creates a URL for that project or group of projects. That URL can then be distributed across "all" supported operations at effectively no cost.

As illustrated below, TopoShare® Enterprise effects the integration of geospatial operations within all downstream planning, design, engineering, construction, and maintenance processes. Through a standard browser, anyone in supported operations can easily locate, access, and interact with existing geospatial project data. Critically important is the ability to locate and communicate directly with the geospatial administrator responsible for the project. This access and communication lay the groundwork for extensive collaboration.

Operations requests for Digital Twin products and more can be communicated directly to the geospatial administrator. The administrator will then supervise the quality-controlled TopoDOT® production process assuring the form, fidelity, and frequency of the Digital Twin is optimized to meet the specific requirements associated with each request. The result is a quality-controlled geospatial process integrated across operations offering unrivaled

communication and collaboration at a minimal cost.

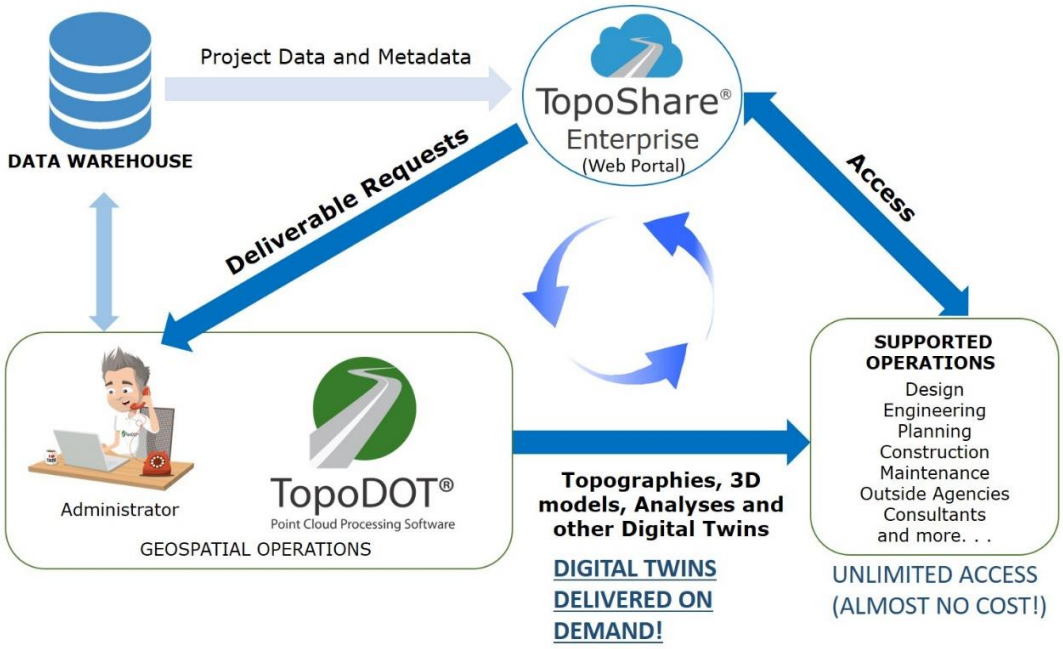


Figure 8: TopoShare® Enterprise creates the Digital Twin "On-Demand" production process

3.1.1.4 Project Interaction through the TopoShare® Enterprise Dashboard

TopoShare® Enterprise responds to the URL by opening up a dashboard featuring a geospatial graphical user interface. The GUI will show the location of every geospatial project that the geospatial administrator had included in the URL's unique access list. When the user selects a specific project, TopoShare® Enterprise will facilitate interaction with the project by transferring selected metadata files stored in the project bin to the browser platform and displaying them over a background map.

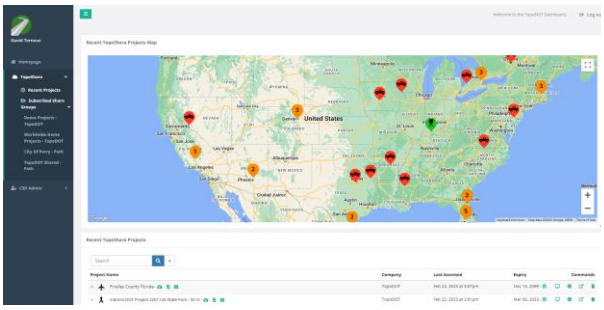


Figure 9: GUI location of every project tagged to URL

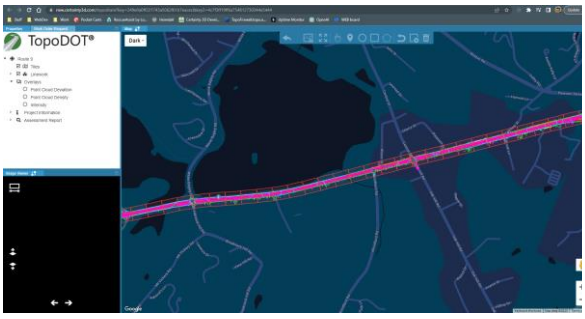


Figure 10:Select and transfer project metadata to browser

These metadata elements describing the project are typically produced during the TopoDOT® Digital Twin production process and stored within the corresponding project data bin in the Project Data Warehouse. Lightweight raster files providing an overview of point cloud data are quickly displayed over the background map. The tile template identifying the location of individual point cloud data files is shown. Overviews in the form of 2D JSON files give visitors insight into the structure and availability of Digital Twins products. Calibrated DPEG images whose location is identified on the map will be identified, downloaded, and displayed within the TopoShare® image window. Since DPEG images have point cloud data overlaid within their file structure, basic measurements can be made in the image.

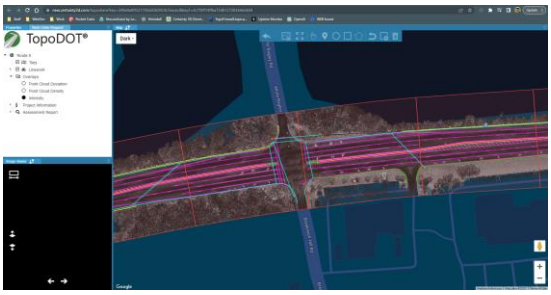


Figure 11: Point cloud raster overview image

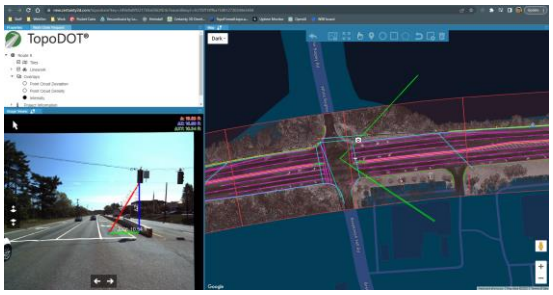


Figure 12: DPEG image with embedded point cloud data

It must be noted that since TopoShare® Enterprise works exclusively with file-based data storage and transfer, there are no high costs which are typically associated with cloud-based processing nor IT infrastructure costs associated with continuous streaming of point cloud data. The result is that every TopoShare® Enterprise user interaction costs typically less than a few pennies—many orders of magnitude less than interactions with cloud-based point cloud viewers.

The administrator does have the option to tag the URL to permit access to the original point cloud data, complete Digital Twin(s) product files, quality assessment documents, control documentation, contracts, essentially any files stored within the project data bin. For example, a user can select one or more data tiles and the corresponding point cloud files will be downloaded to their desktop. Aforementioned files can all be selected and downloaded from a list within the user's TopoShare® Enterprise dashboard.

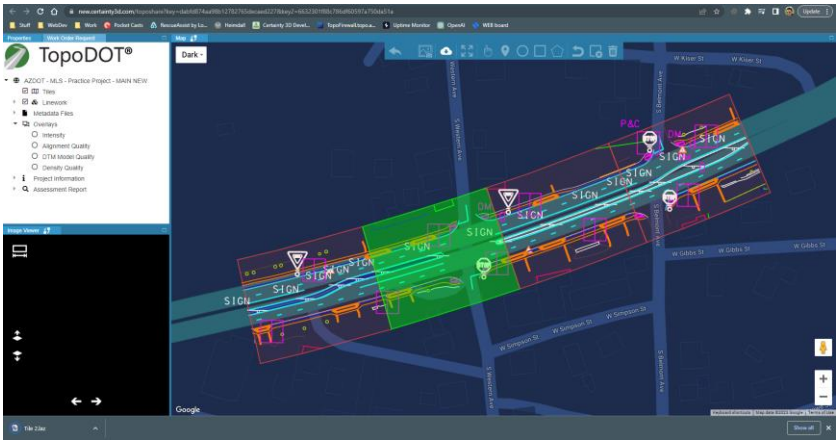


Figure 13: Select tile(s) to download corresponding point cloud data from warehouse

4.1 Integration of Supplemental Applications Within the TopoShare® Process

The TopoShare® process is not positioned to compete with any GIS or point cloud viewing applications. TopoShare® is actually in effect complimentary to these platforms by facilitating their creation and on-going maintenance.

Keep in mind that TopoShare® is designed to maintain the provenance of each instance of project data acquisition. Data provenance is maintained within the Project Data Warehouse by organizing each project into its individual bin. Such organization is critically important *if geospatial operations is to assure and accept responsibility for the quality of each Digital Twin delivered!*

In contrast, web-based point cloud viewing applications specialize in enhanced interaction with point clouds and images. They accomplish this interaction by publishing data to dedicated servers moving data through IT infrastructure optimized for real-time data streaming. This data interaction is orders of magnitude more expensive to execute than TopoShare® interaction. While these viewers do offer some practical utility within some aspects of the design process, the provenance of this data, its documented lineage to certified coordinate control reference networks, its quality assessment documentation is generally not tagged to the data being viewed. Absent this information, the data cannot reliably support quality controlled Digital Twin production. Even if the data were tagged with this metadata, the interpretation of this quality data would in effect be transferred to anyone accessing the viewer and attempting to extract information, execute an analysis or develop a Digital Twin. Since this could often be a person without geospatial experience nor authority to guarantee the quality of the delivered product, the Digital Twin production process can easily become disorganized with no clear lines of responsibility for outcomes.

The utility of GIS databases is quite different. Since GIS databases typically offer little capability to productively extract GIS asset and related attribute data from the project data, point clouds are of limited use on these platforms outside of a general reference. In contrast, GIS asset extraction within the quality controlled TopoDOT® process will yield extremely information rich asset databases formatted for seamless export to any GIS database.

As mentioned earlier, the TopoShare® process is therefore positioned to support these and any other applications. Illustrated below is the simple modification to the TopoShare® process to include the geospatial operations publishing the appropriate data to additional viewer or GIS applications. This makes operational sense as geospatial operations will typically be responsible for implementing and maintaining these applications.

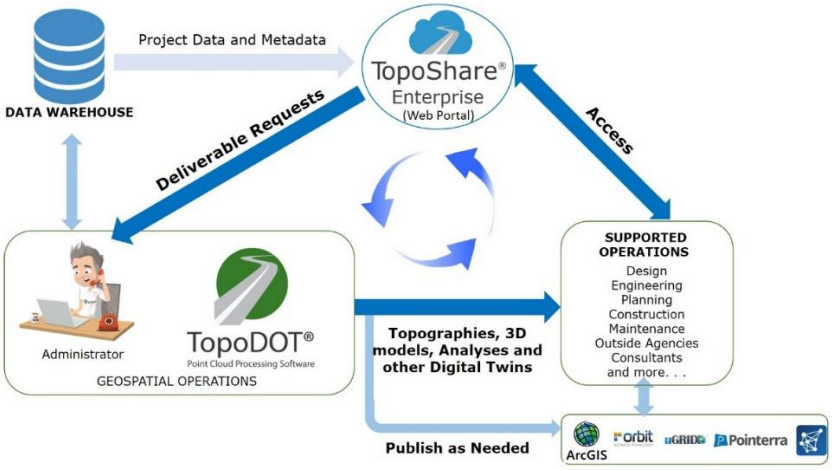


Figure 14: The TopoShare process is positioned to support GIS and cloud-based data viewer applications

5.1 TopoShare® Process Costs

The cost of implementing the complete TopoShare® process is extremely low. Since TopoShare® lets you create your Data Warehouse in your Amazon S3 or Azure account, there are no costs outside a few cents per gigabyte to store data. As TopoShare® project data interaction is exclusively file-based, the high cost of cloud-based point cloud viewers is avoided. For example, a typical TopoShare® Enterprise project data interaction will typically require a few cents in data transfer costs. This makes the scalability of the TopoShare® process effectively unlimited across operations.

As mentioned previously, the TopoShare® Administrator program and TopoShare® Basic portal are provided to the TopoDOT® user community at no cost. The only real cost associated with implementing the TopoShare® process is for the TopoShare® Enterprise web-page portal. TopoShare® Enterprise is currently a fixed annual price of $18,000 for an *unlimited* number of projects. As of early 2023, typical TopoShare® users access literally

hundreds of projects from their respective Digital Warehouses. As those numbers increase, their TopoShare® Enterprise price per project decreases accordingly.

6.1 Conclusions

The TopoShare® process has proven to be extremely effective in integrating geospatial operations into next generation design processes. Successful TopoShare® process implementations within the worldwide TopoDOT® user community have consistently demonstrated dramatically enhanced communication and collaboration across operations.

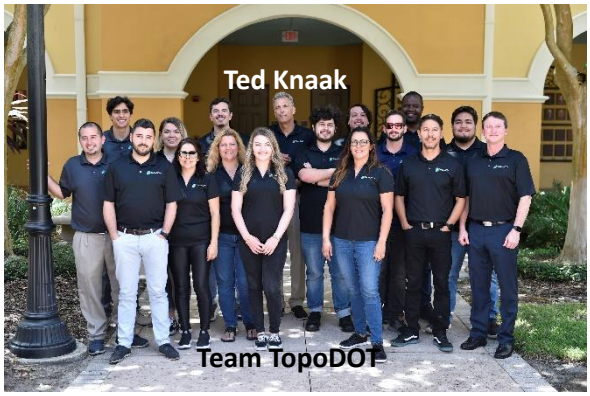
Development of the TopoShare® process was primarily motivated by a rethinking of the Digital Twin production process. TopoShare® was developed to fundamentally shift Digital Twin production from focus on a single universal Digital Twin to a continuous On-Demand process. It was found that the TopoShare® On-Demand process is fundamentally self-optimizing in performance and cost. In contrast to the universal Digital Twin concept, the TopoShare® process efficiently responds to specific operational requests for topographies, models, simulations, and analyses with Digital Twins optimized to specific requirements when and where they are needed.

The TopoShare®/TopoDOT® workflow positions geospatial operations in administrative control of a quality-controlled production process. This avoids the serious risk of liability associated with providing general universal rights across all operations to analyze and extract actionable information from Digital Twins absent expertise and experience required to confirm that the information will meet operational objectives.

On-demand Digital Twin production executed by the TopoShare®/TopoDOT® process was shown to be optimized to achieve the highest performance at the lowest possible cost. TopoShare®'s file-based data storage and transfer strategy keeps the cost of project data interaction negligible thereby allowing for unlimited scalability across operations.

Finally, TopoShare®'s low cost of data storage and transfer serve to facilitate the publication of data to web-based point cloud viewers, GIS database and other applications supported by geospatial operations. The TopoShare®/TopoDOT® process is therefore positioned as complimentary to any such products.

Biographical Notes



Ted Knaak is president and founder of TopoDOT LLC. Ted began his career as control systems analyst for GE Space Systems in 1983. In 1992, Ted founded Riegl USA spending 17 years applying LiDAR hardware technology to industrial, survey and military applications. In 2012, Ted started TopoDOT LLC. Today with 6000+ users worldwide, TopoDOT® is a leading software application for Digital Twin production in the areas of transportation corridor, civil infrastructure and general survey applications. Ted holds Masters degrees in Electrical and Mechanical Engineering.

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